

Shuttle Transportation System Case-Study Development

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Project Title: Shuttle Transportation System Case-Study Development**Abstract**

A case-study collection was developed for NASA's Space Shuttle Program. Using lessons learned and documented by NASA KSC engineers, analysts, and contractors, decades of information related to processing and launching the Space Shuttle was gathered into a single database. The goal was to provide educators with an alternative means to teach real-world engineering processes and to enhance critical thinking, decision making, and problem solving skills. Suggested formats were created to assist both external educators and internal NASA employees to develop and contribute their own case-study reports to share with other educators and students. Via group project, class discussion, or open-ended research format, students will be introduced to the unique decision making process related to Shuttle missions and development. Teaching notes, images, and related documents will be made accessible to the public for presentation of Space Shuttle reports. Lessons investigated included the engine cutoff (ECO) sensor anomaly which occurred during mission STS-114. Students will be presented with general mission information as well as an explanation of ECO sensors. The project will conclude with the design of a website that allows for distribution of information to the public as well as case-study report submissions from other educators online.

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Introduction

In an effort to provide educators and students with additional resources related to NASA Space Shuttle missions, the Shuttle Transportation System (STS) Case-Study Development project was created. With this project, a case study collection was developed based on lessons learned throughout the thirty years of the Shuttle program. Among the first lessons investigated was the engine cutoff sensor anomaly which first occurred during mission STS-114.

Investigation Summary

Twenty-four propellant sensors are within the Shuttle's External Tank (ET) – twelve in the oxygen section and twelve in the hydrogen section. Of the dozen sensors in the hydrogen section, four are used to measure the amount of propellant present in the tank before launch. Known as engine cutoff or ECO sensors and mounted on a single, shock-isolated carrier plate approximately four feet from the very bottom of the liquid hydrogen (LH₂) fuel tank, they are part of a backup system designed to protect the Space Shuttle Main Engines (SSMEs) from catastrophic failure due to propellant depletion [3]. The entire ECO sensor system in the LH₂ section of the external tank includes a platinum wire sensing element mounted on an alumina Printed Wiring Board (PWB) and encased in an aluminum housing [4, p.8]. Other components include harnesses, a series of connectors, and point sensor box (PSB) electronics in the orbiter. The sensors in the tank send electronic signals through wires to the PSB in the orbiter, which in turn sends data signals to the orbiter's onboard computer system.

The point sensor box services all twenty-four sensors within the external tank, including the four engine cutoff sensors within the LH₂ section. Mounted on a coldplate in avionics bay-5 of the orbiter, the PSB supplies each sensor circuit with a constant current and reads the voltage across each sensor's thermosensor wire element [2, p.3]. The platinum wire sensing element of the sensor acts as a variable resistance which changes on exposure to cryogenic liquid [4, p.9]. At ambient temperature, when the sensor wire resistance is high, the measured voltage is considered above the preset trip level in the box and provides a "dry" indication. At liquid hydrogen temperature, -423°F, the voltage drops below the trip level and the signal is perceived as "wet". Flight software checks for the presence of "wet" indications from the sensors to indicate the presence of propellant and "dry" indications to indicate the engines are at risk of running too low. The LH₂ ECO sensors are coded to read "wet" once propellant loading begins to mean they are covered with cryogenic propellant [3]. Should the PSB electronics fail to provide an output signal or if an open circuit develops between the PSB and the sensor, a "wet" state is also indicated.

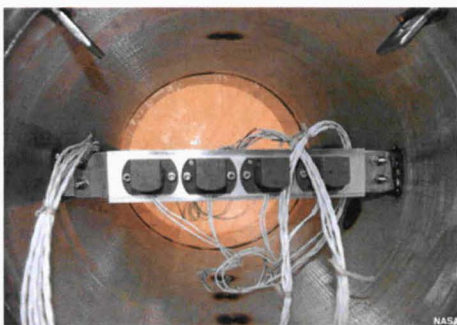


Fig.1. Engine cut-off sensors located at bottom of external tank [1].

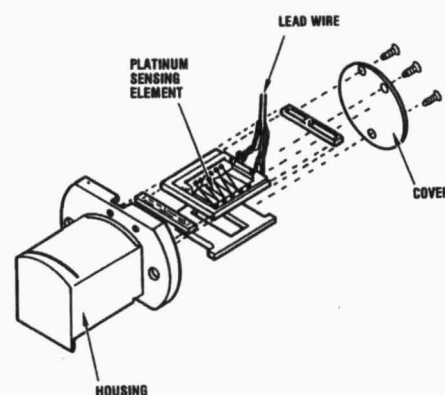


Fig. 2. ECO Sensor System Overview [2].

Therefore, the box design includes self-check electronics which are activated by ground simulation commanding to help distinguish between a "wet" sensor output and a failed "wet" output [2, p.3].

Responsible for protecting the Shuttle's main engines by triggering their shutdown in the event fuel runs unexpectedly low, the low-level cut-off (LLCO) sensor system is quite essential to proper Shuttle function. If a low level of liquid hydrogen were to occur in the tank due to the main engines using more liquid hydrogen than predicted, it is crucial that the sensory system detects the condition immediately to avoid engine fire or explosion. The use of four sensors helps to ensure that multiple sensors agree that the tank is either empty, or not. The first "dry" indication from any of the ECO sensors is discarded to protect against a faulty sensor, but the presence of at least two more "dry" indications will result in a command to shutdown the SSMEs [4, p.9]. Once at least two of the four sensors agree that the liquid hydrogen level is low, the main engines then shut down.

Technical Contributions

Reports

Basic technical knowledge was beneficial in investigating the engine cutoff sensor anomaly which led to the July 2005 scrub of mission STS-114. As a mechanical engineer, it was important to understand the mechanics of the hardware components as well as the electrical connections to other systems such as the point sensor box within the Shuttle. This understanding allowed for easier translation and presentation of the material to secondary and higher education students as well as educators. Extensive technical writing was completed to portray not only the role of the engine cutoff sensors, but to also describe the testing and troubleshooting procedures completed to investigate the anomaly.

Process Development

Additional technical contributions to the STS Case Study Development project included the development of process flow charts. To streamline the entire Case Study process, from report creation to website submission, multiple process flow charts were designed using iGrafx FlowCharter 2007 software. The goal was to aid case study contributors, including educators, industry personnel, and NASA employees, in developing their own case study reports and in submitting them to Case Study Managers for review and publishing to the KSC Education website. A process chart detailing the review process for Case Study Managers, Subject Matter Experts, and other reviewers was also created.

Successful completion of the various process charts required weeks of collaboration with KSC's legal office, Export Control office, website administrators, and various Education Office personnel. As a new case study collection, every process required of contributors, managers, and its reviewers had to be carefully outlined. This required an understanding of what type of materials could be publicly accessible and which materials would have to be inspected by Export Control to avoid the release of sensitive information. It was also necessary to speak with legal representatives to determine the copyright release documents that would be required of contributors.

Website Development

The final stage of the STS Case Study Development project will conclude with the creation of a website. NASA's CMS or Competency Management System was utilized for website training, which is required to gain access to update NASA webpages. Basic html skills were also enhanced during the training. Additional tasks will include creating html code to display Shuttle Case Study information, including case study reports and images, on the KSC Education website.

Applications from Embry-Riddle Courses

Various skills learned or enhanced through taking Embry-Riddle graduate courses were used throughout the development of the Shuttle Case Study Project. Graduate courses at ERAU definitely encourage students to present their research or project findings to other students and professors. Specifically, speaking skills as well as basic presentation formatting skills were useful in making professional presentations to NASA supervisors and mentors. Understanding the user requirements for a public system, knowledge gained from Dr. White's Clean Energy Systems course, was also instrumental for the development of the STS Project. It greatly strengthened the design of the process charts to include operations from start to finish for a variety of users.

Current Status of Case Study Development Project

While the project will continue on indefinitely as educators, industry personnel, and NASA employees continue to contribute case study reports, the development of the project is within its final stages. Case study reports have been completed. Suggested outlines or formats have been created to assist contributors in creating their own reports. The review process for submitted reports has been outlined as well as the responsibilities of each reviewer. During the fall semester, the development of the website will continue. Additional html training may be required to allow for proper upload of content without assistance. Issues must also be addressed with website administrators to ensure all case study content will be published in a timely manner. Much was accomplished during the 10-week summer semester and the project is expected to move forward successfully.

Personal Reflection

Motivation to Apply

I first noticed the STS Case Study Development project around February 2012. Initially, I saw it as just one of the many opportunities available through SOLAR, NASA's application portal. Upon further review, however, I realized the project was located at KSC. I knew that I liked working at KSC during previous internships and really wanted to return. Thus, the STS Case Study Development opportunity became one of my top choices and one of the very first opportunities I applied for through SOLAR. I was excited about the chance to be involved with some official publications as well as to learn more about NASA Shuttle missions. With the Shuttle program recently ending, I thought it would be interesting to get to interview NASA engineers and contractors involved with the Shuttle throughout its 30 year history. All of the details of the project were not clear, but I was anxious to learn more.

Experience Gained

I benefited greatly from participating with the STS Project! I learned unique details of the Shuttle Program through interviews with engineers and contractors whose job was to prepare and launch the Shuttle vehicles. I gained insight into engineering management responsibilities. Interviewing former Shuttle Mission Management Team members gave me a backstage pass into decisions and issues I may possibly face in the future. My teamwork and collaboration skills were also strengthened, which was very important considering I see this area as a personal weakness. Throughout the summer, I worked with everyone from lawyers, to engineers, to graphic designers, to educators, and accountants who all had something to teach me even if it was as simple as how to access a software program or view someone's calendar in Outlook. I also enhanced my technical writing and public speaking skills which will be valuable assets for my future career.

Memorable Moments

I will never forget the day I had lunch with Embry-Riddle alumni astronaut Nicole Stott! She is an amazing female astronaut who was open to answering any and all of my questions related to traveling to space and living on the International Space Station. She provided some great advice on applying to the astronaut program and for moving forward with a career as an engineer. She has definitely become one of my newest role models.

I will also never forget seeing Shuttle Atlantis in person. On its roll out day from OPF-1 to the VAB, I was less than 20 feet from it! It is such an amazing vehicle. If only for moments like it, I would recommend an internship with NASA to everyone!

Acknowledgments

Special thanks to the Florida Space Grant Consortium and the Education Projects Division at NASA Kennedy Space Center for helping to sponsor the project. Thanks to mentor Grace Johnson (NASA KSC) for her unending support and advice throughout the summer. Thanks to Stephanie Nicholas, my fellow intern, for her hard teamwork and cooperation. Everyone's work and support is greatly appreciated!

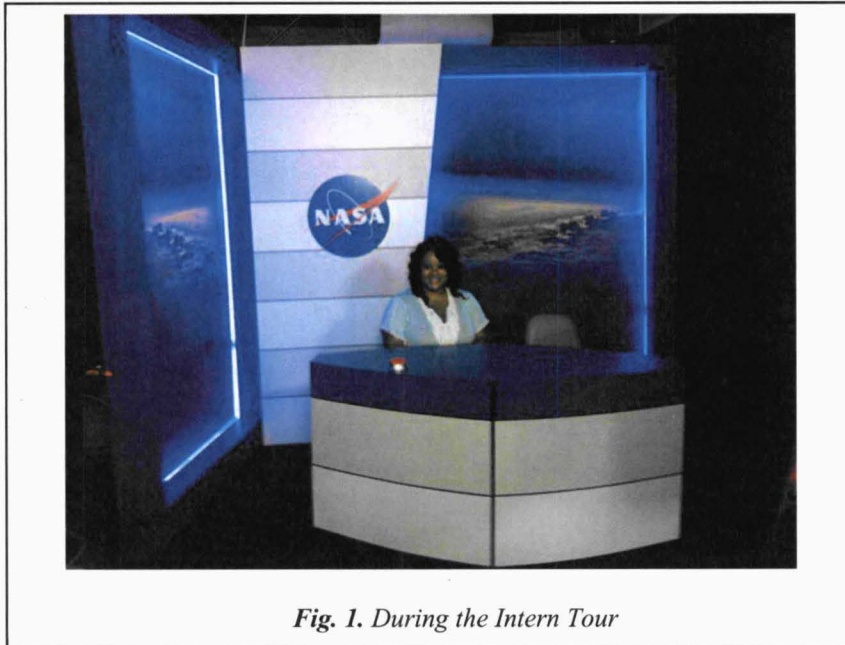
Consent Statement

I, Khadijah Ransom, give my consent to allow the NASA Florida Space Grant Consortium to use my quotes, pictures, and video in reporting to NASA Headquarters.

References

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Photos



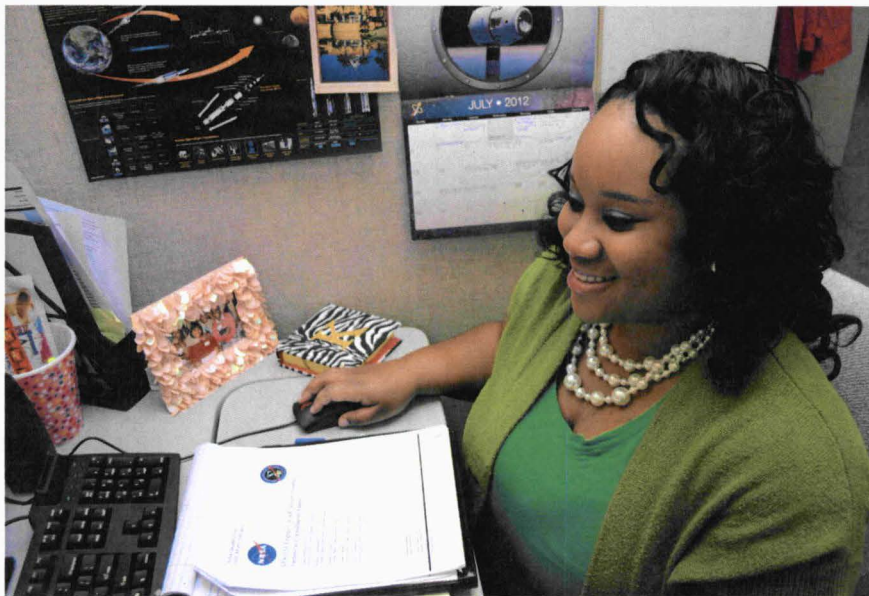


Fig. 3. Happy to be at Kennedy Space Center



Fig. 4. Me with Astronaut Nicole Stott



Fig. 5. Shuttle Atlantis Rollout

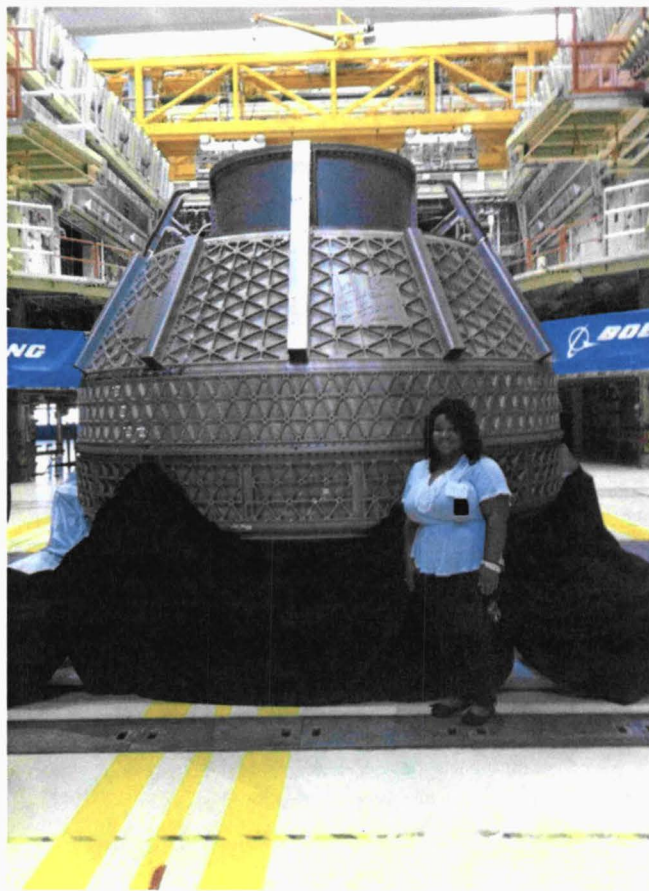


Fig. 6. With Mock-Up of Orion Capsule